Influence of the change in land use on the soil water properties of Andisols (Tenerife, Canary Islands, Spain)

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1. Abstract

Undisturbed Andisols are considered to be resistant to water erosion, a characteristic closely associated with their high porosity and high structural stability. The aim of the present work is to study, through field rainfall simulation tests, the influence on infiltration and erosion when such soils are put to different uses.

Four sites were chosen, all of them located on the northern face of the island of Tenerife (Spain), between 825-1,400 m.a.s.l. The soils are allophanic Andisols (Typic/Lithic Hapludands -Sites 1 and 2- and Typic Haplustands - Site 3) and non-allophanic Andisols (Ultic Fulvudands - Site 4) under different uses. The results obtained were as follows: In Site 1, infiltration decreased in the following order: potential vegetation (green forest - 86 mmh^{-1}), repopulated pine (28 mmh^{-1}), repopulated pine with selective cuttings (14 mmh^{-1}) and deforested (6 mmh^{-1}). The field plot with green forest recorded 95% higher infiltration than the deforested plot. In Site 2, where the natural pine cover was removed in some parts to allow cropping, a slight decrease in infiltration was seen (29 to 19 mmh^{-1}). In Site 3, where pine forest coexists with zones repopulated with eucalyptus, the highest values were observed in the natural parts (44 vs. 31 mmh^{-1}). In Site 4, the infiltration in the green forest was 35 mmh^{-1}, compared to 21 mmh^{-1} in the pine forest. Sediment generation was highest (587 gm^{-2}) in the cropped plot (Site 2) and less than 20 gm^{-2} in the other cases, except the eucalyptus repopulated plot (Site 3, 32 gm^{-2}) and the deforested plot (Site 1, 56 gm^{-2}). The results demonstrate the importance of changes in land use in terms of the generation of erosion processes.

2. Introduction

The majority of studies conducted are in agreement that Andisols are soils with a high infiltration rate and/or hydraulic conductivity (Warkentin and Maeda, 1980; Nanzyo et al., 1993) and low erodibility, a characteristic closely associated with their high porosity and high structural stability (Maeda and Soma, 1985; Nanzyo et al., 1993). They are generally considered to be erosion-resistant (Warkentin, 1983; Shoji et al., 1993) and their stability is attributed to their high permeability and the cohesion between aggregates. However, these qualities are normally associated with undisturbed soils. Soil drying, loss of plant cover and - in the long term - impoverishment of organic material in the surface horizon can induce severe water erosion (Warkentin and Maeda, 1980; Poulenard et al., 2001).

The island of Tenerife (Canary Islands, Spain), which is 2,054 km^2 in size and has a highest point of 3,718 m.a.s.l., has a wide variety of microclimates, depending on altitude and orientation. Sub-aerian geological materials - volcanic for the most part - date back to various ages, from the Miocene to the Holocene. The most recent volcanic eruption occurred in 1909. Of the very diverse soils found on the island, Andisols are the most characteristic, although their presence is limited to certain altitudes. The wide variety of Andisols includes very young soils rich in volcanic glass and developed soils which are andic on account of their organoaluminium complexes. Allophanic soils are also present (Fernández and Tejedor, 1975; Fernández Caldas et al., 1982). The location of the developed andisols, both allophanic and non-allophanic (which are studied here), on the island is associated with heights featuring a predominance of green forest vegetation (in the north of the island, between 600-1000 m.a.s.l.) and pine forest (around 1000 m.a.s.l. in the north, 800 m.a.s.l. in the south).

A number of zones in these altitudinal strips have been modified down the years as a result of changes in land use and management for farming or forestry. Some - the lowest-lying - were stripped of their cover and put to agricultural use. Others, higher up, were cleared in order to introduce more profitable tree species (*Eucalyptus sp.* and *Pinus radiata* mainly). A programme put in place to restore the original cover involves clearing to eliminate the new vegetation, repopulation with native species, and selective cutting to achieve a more sustainable forest density. These activities are also affecting the characteristics and natural conditions of the soils in question, including their hydrologic behaviour.

The aim of the present work is to study, using field rainfall simulation tests, the influence on infiltration and erosion when the soils are put to different uses.

3. Methods

Four sites were chosen for the study, all of them located on the northern side of the island and situated between 825-1400 m.a.s.l. The soils are allophanic Andisols (Typic/Lithic Hapludands-Sites 1 and 2 and Typic Haplustands-Site 3) and non-allophanic Andisols (Ultic Fulvudands- Site 4) under different uses.

Table 1 describes the studied plots on the 4 sites. In Site 1 management varies from potential state (green forest) to the most degraded state (deforested areas) and includes repopulated areas as well as repopulated areas in which selective cutting has been carried out. In Site 2 the natural pine cover was removed in some parts to allow cropping, although in some cases (such as this one) the plots were abandoned and have remained so. In Site 3 pine forest coexists with zones repopulated with eucalyptus. Lastly, in Site 4 some areas with potential vegetation (green forest) were repopulated with pines.

Table 1 Plot description

Site	Soil	Use/management
Site 1	Typic/Lithic Hapludands	Green forest
		Repopulated pine
		Repopulated pine with selective cutting
		Deforested
Site 2	Typic/Lithic Hapludands	Pine forest
		Cropped
Site 3	Typic Haplustands	Pine forest
		Repopulated eucalyptus
Site 4	Ultic Fulvudands	Green forest
		Repopulated pine

In order to determine infiltration, a rainfall simulator with the following characteristics was used (Pla, 1983, Fonseca, 2006): 35 x 25 x 30 cm metal box with nozzles in the bottom, 2.5 cm apart (diameter of drops = 2-3 mm). The box's 4 adjustable legs were set at 2 m height. Prior to installing the rainfall simulator, study zones were marked out using 30 cm-tall metal sheets. Each area measured approximately 875 cm^2 with a slope of around 20%. At the end of the slope a 25 cm-wide collector was semi-buried to collect runoff and sediment. Rainfall of variable intensity between 80-100 mmh^{-1} was simulated for periods of 30-45 minutes.

4. Results

As shown in Table 2 and Figure 1, the change in use and/or management leads to a reduction (at times drastic) in the infiltration rate and in sediment production.

Table 2 Infiltration rate and sediment generation

Site	Use/management	Infiltration rate (mmh^{-1})	Sediment yield (gm^{-2})
Site 1	Green forest	86	10
	Repopulated pine	28	9
	Repopulated pine with selective cutting	14	10
	Deforested	6	56
Site 2	Pine forest	29	10
	Cropped	19	587
Site 3	Pine forest	44	11
	Repopulated eucalyptus	31	32
Site 4	Green forest	35	11
	Repopulated pine	21	18

Site 1 presents the greatest reduction in infiltration rate, which changes from 86 mmh^{-1} for the potential vegetation to 28 mmh^{-1} in the repopulated pine, 14 mmh^{-1} in the repopulated areas with selective cutting and 6 mmh^{-1} in the deforested areas. In other words, a reduction of 95% was seen in the rate between the potential situation (green forest) and the most aggressive action (deforested area).

In the other zones, a reduction in the infiltration rate is also seen, but it is less pronounced, representing between 30 and 40% of the potential figure. In Site 2 the rate changes from 29 mmh^{-1} in pine forest to 19 mmh^{-1} in the cropped and abandoned areas. In Site 3, the zone with pine forest presents an infiltration rate of 31 mmh^{-1}, compared to the 21 mmh^{-1} recorded in the zone with repopulated eucalyptus. Lastly, in Site 4, the change in vegetation has led to a reduction in the infiltration rate from 35 mmh^{-1} in the zones with potential vegetation (green forest) to 21 mmh^{-1} in those repopulated with pine trees.

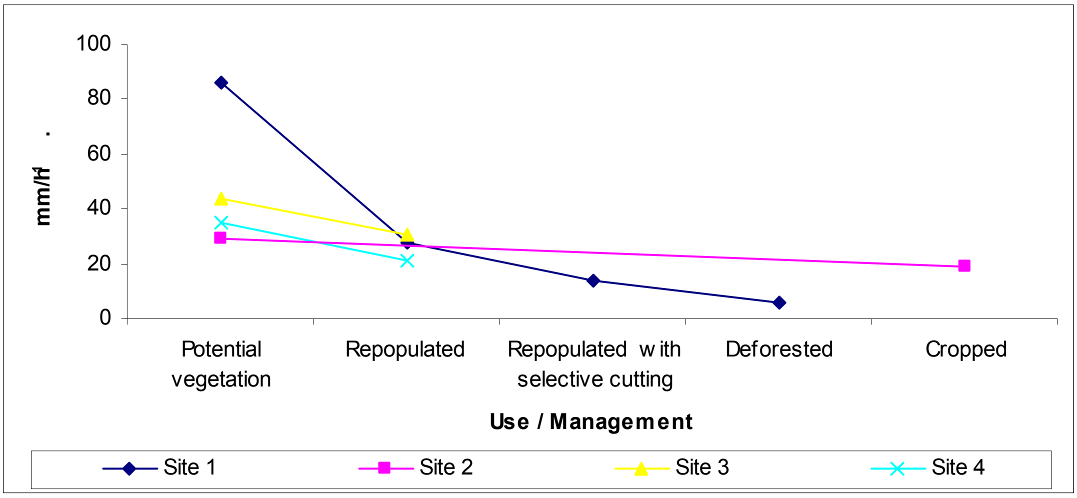

Figure 1 Infiltration rate under different land uses

Concerning sediment production, the highest figures are seen where use or management has been most aggressive, particularly where the plant cover has been partly or totally eliminated. The former farming zones that now lie abandoned in Site 3 present the highest sediment production figure (587 gm^{-2}), followed by the deforested areas in Site 1 (56 gm^{-2}) and, in Site 3, the repopulated eucalyptus areas (32 gm^{-2}).

In the other zones, despite the lower infiltration rate and increased run-off as a result of the change in use/management, no significant differences are seen in sediment production, which is always below 20 gm^{-2}. In these cases, in spite of the change in management, the presence of a dense plant cover affords considerable protection for the soil against erosive processes.

5. References

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